US009318770B2

(12) **United States Patent**
Kobayashi et al.

(10) **Patent No.: US 9,318,770 B2**
(45) **Date of Patent: Apr. 19, 2016**

(54) **BATTERY AND METHOD OF MANUFACTURING BATTERY**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 269 days.

(21) Appl. No.: **14/237,304**

(22) PCT Filed: **Aug. 9, 2011**

(86) PCT No.: **PCT/JP2011/068163**
§ 371 (c)(1),
(2), (4) Date: **Feb. 5, 2014**

(87) PCT Pub. No.: **WO2013/021463**
PCT Pub. Date: **Feb. 14, 2013**

(65) **Prior Publication Data**
US 2014/0178731 A1 Jun. 26, 2014

(51) **Int. Cl.**

H01M 2/12	(2006.01)
H01M 10/04	(2006.01)
H01M 2/26	(2006.01)
H01M 10/0525	(2010.01)
H01M 2/30	(2006.01)

(52) **U.S. Cl.**
CPC ***H01M 10/0431*** (2013.01); ***H01M 2/12*** (2013.01); ***H01M 2/263*** (2013.01); *H01M 2/30* (2013.01); *H01M 10/0525* (2013.01); *Y02T 10/7011* (2013.01); *Y10T 29/49108* (2015.01)

(58) **Field of Classification Search**
CPC .. H01M 2/12; H01M 2/263; Y10T 29/49108; Y10T 10/7011
USPC 429/94, 98, 121, 122, 517; 29/623.1
See application file for complete search history.

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Assistant Examiner — Monique Wills
(74) *Attorney, Agent, or Firm* — Sughrue Mion, PLLC

(57) **ABSTRACT**

It is a task of the invention to provide a battery that allows a gas produced inside a flat wound electrode body to be easily discharged to the outside of the electrode body, and restrains an electrolytic solution (a retained electrolytic solution) extruded from the flat wound electrode body through charge/discharge from directly flowing out to the outside of the flat wound electrode body, and a method of manufacturing this battery. The battery is equipped with a flat wound electrode body, a collector member, and a retained electrolytic solution. The flat wound electrode body has an active material layer wound portion that is obtained by winding an electrode plate, has a flat oval cross-section, and has a wound active material layer forming portion, and an exposed wound portion that has a wound foil exposed portion. An exposed wound central portion is detached from at least one of two exposed wound end portions while maintaining contact with an active material layer wound portion that is adjacent to the exposed wound central portion in an axial direction. The collector member is joined to the exposed wound central portion.

4 Claims, 11 Drawing Sheets

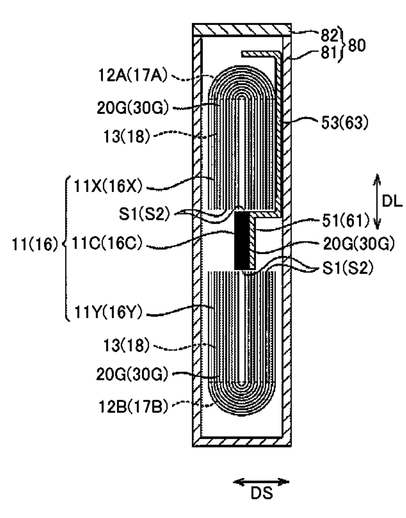

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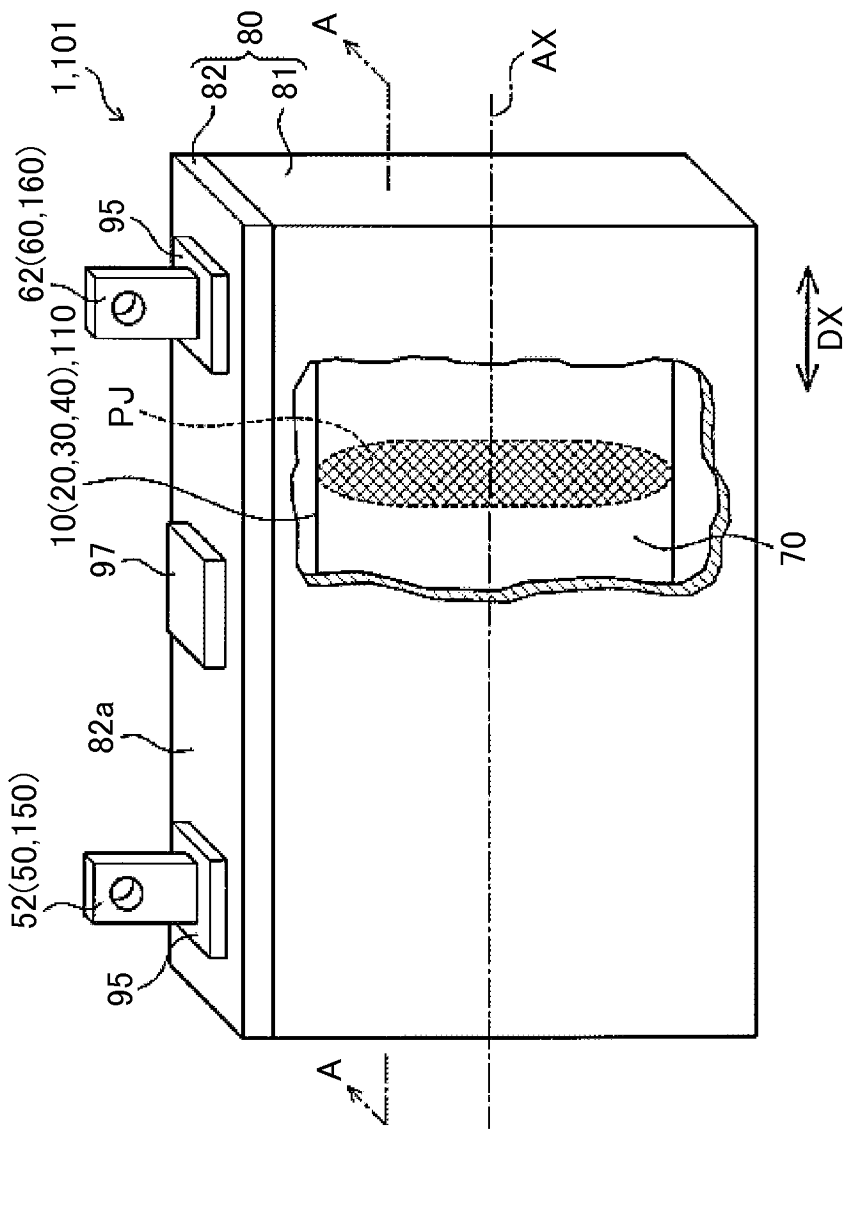
FIG. 1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82
81
A
AX
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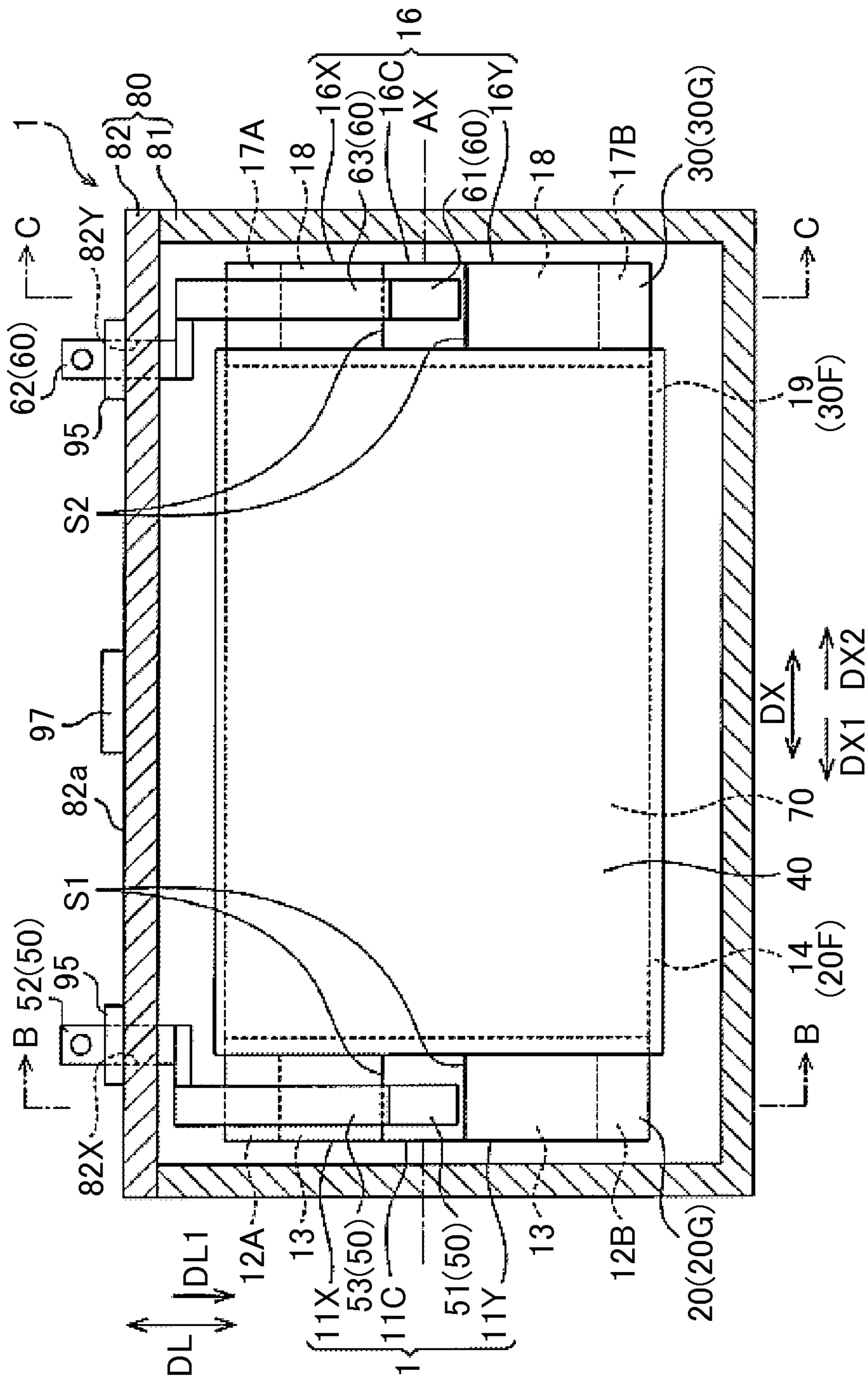
82a
52(50,150)
95
A

FIG. 2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16Y
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C
82Y
62(60)
95
S2
19
(30F)
97
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DX
DX1
DX2
70
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S1
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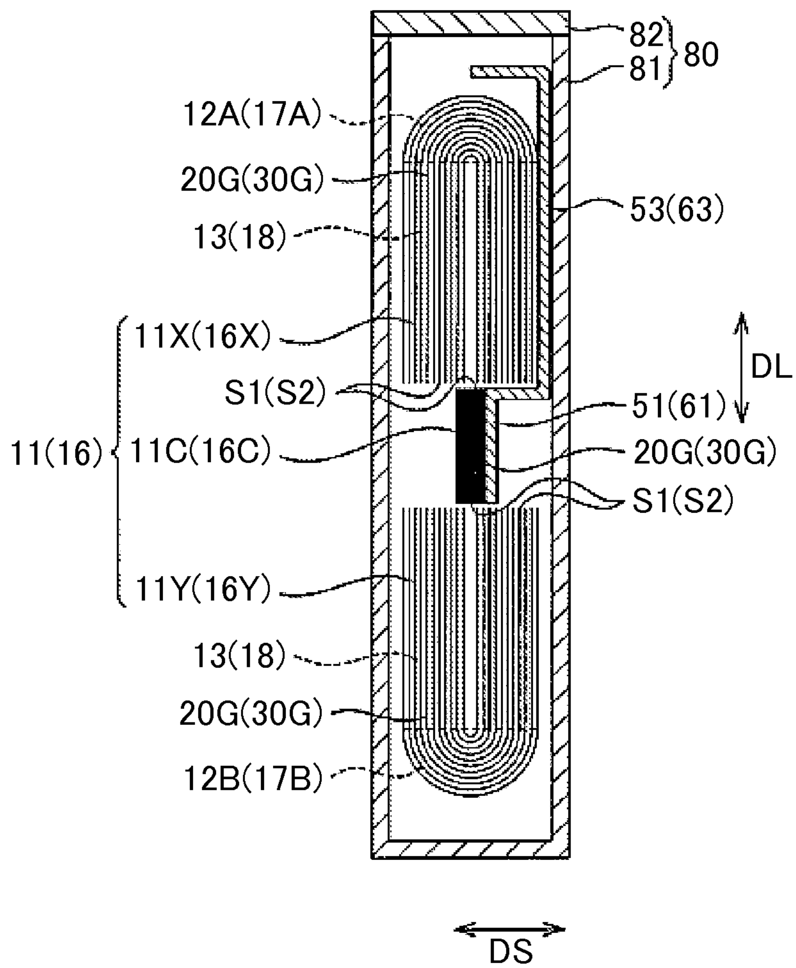
11
DL
DL1

FIG. 3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13(18)
53(63)
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S1(S2)
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11(16)
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S1(S2)
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13(18)
20G(30G)
12B(17B)
DS

FIG. 4

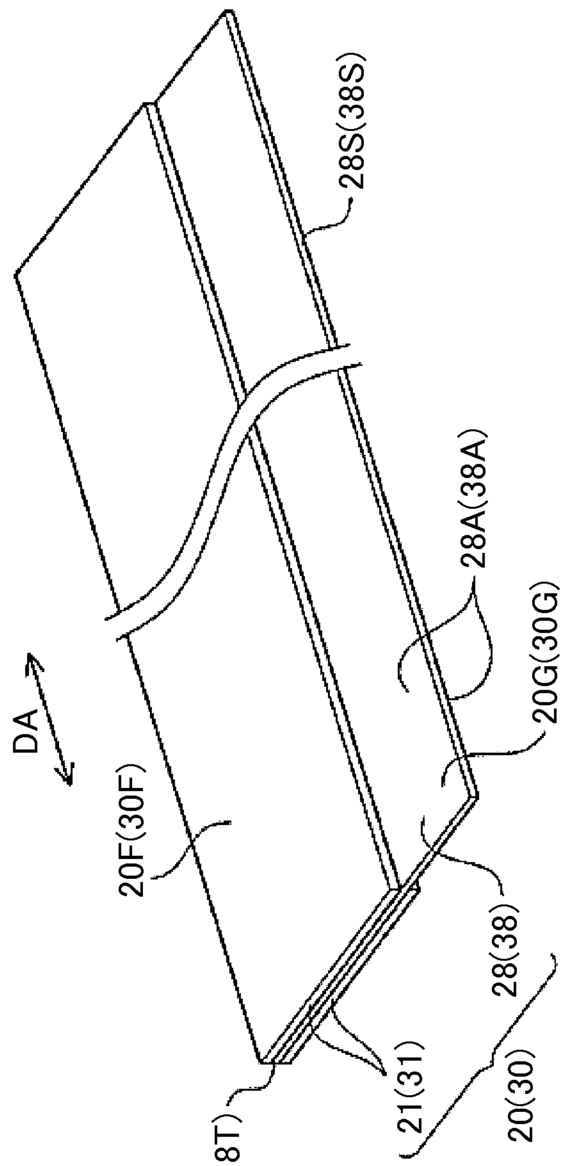
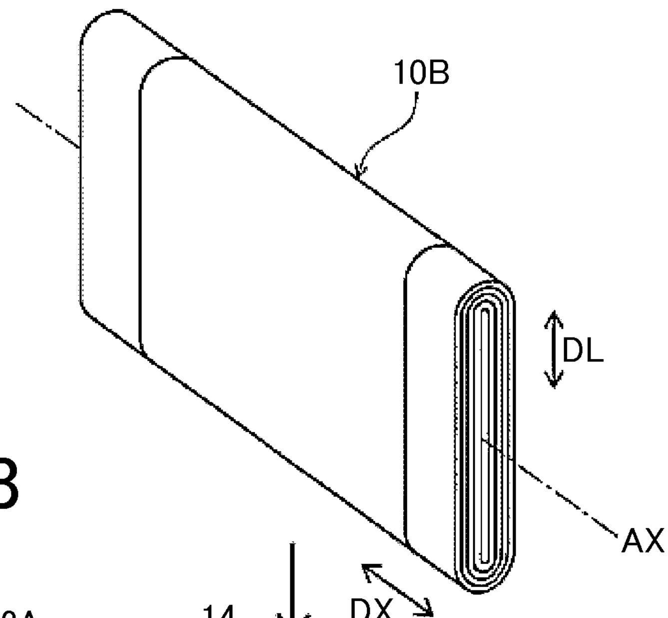


FIG. 5A


10B
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AX
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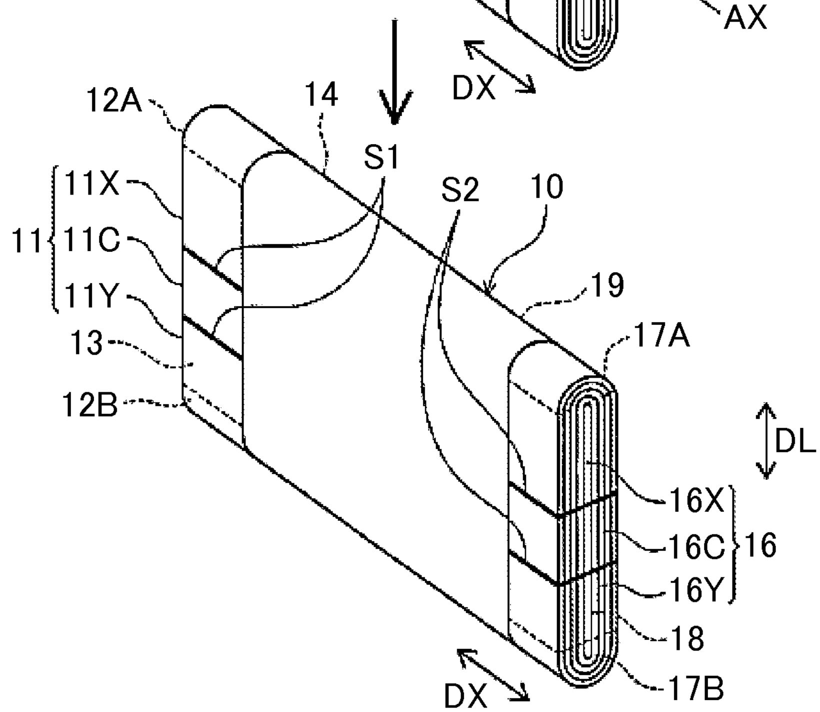
FIG. 5B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14
S1
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11
11C
11Y
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S2
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17A
DL
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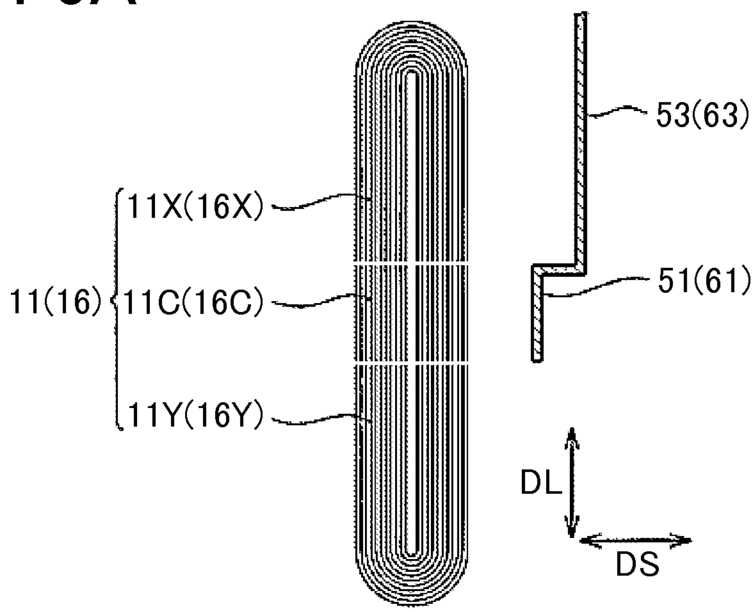
16
16Y
18
17B
DX

FIG. 6A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51(61)
11(16)
11C(16C)
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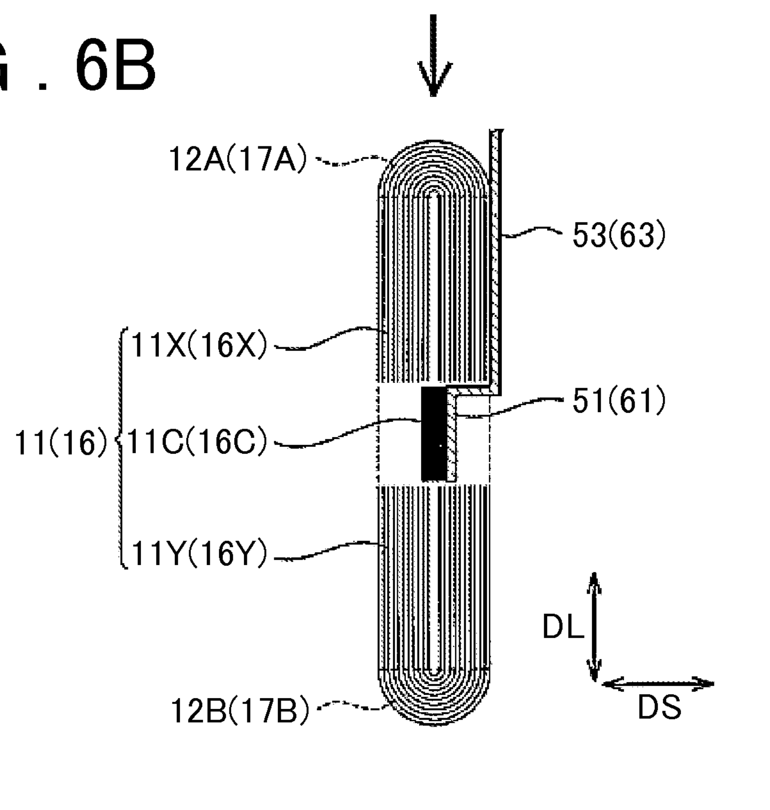
DL
DS

FIG. 6B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51(61)
11(16)
11C(16C)
11Y(16Y)
DL
DS
12B(17B)

FIG. 7A

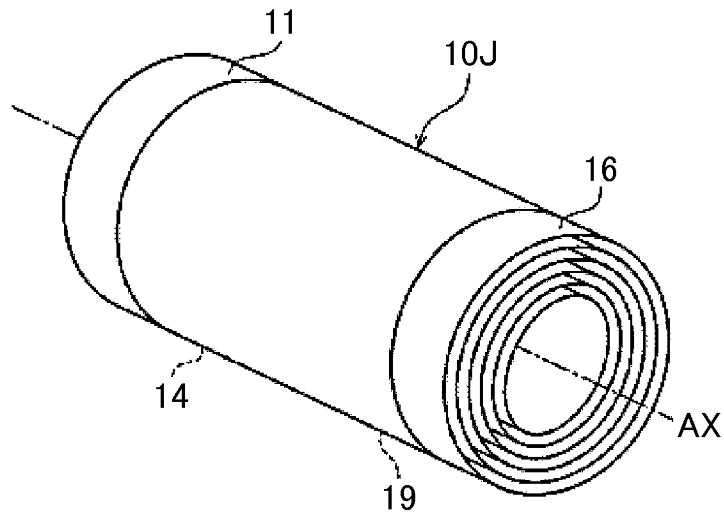


FIG. 7B

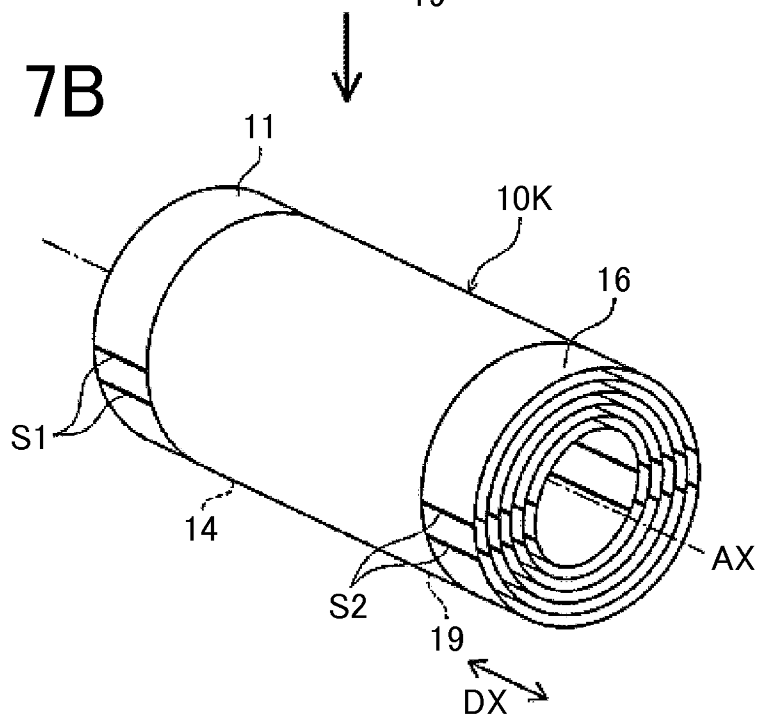
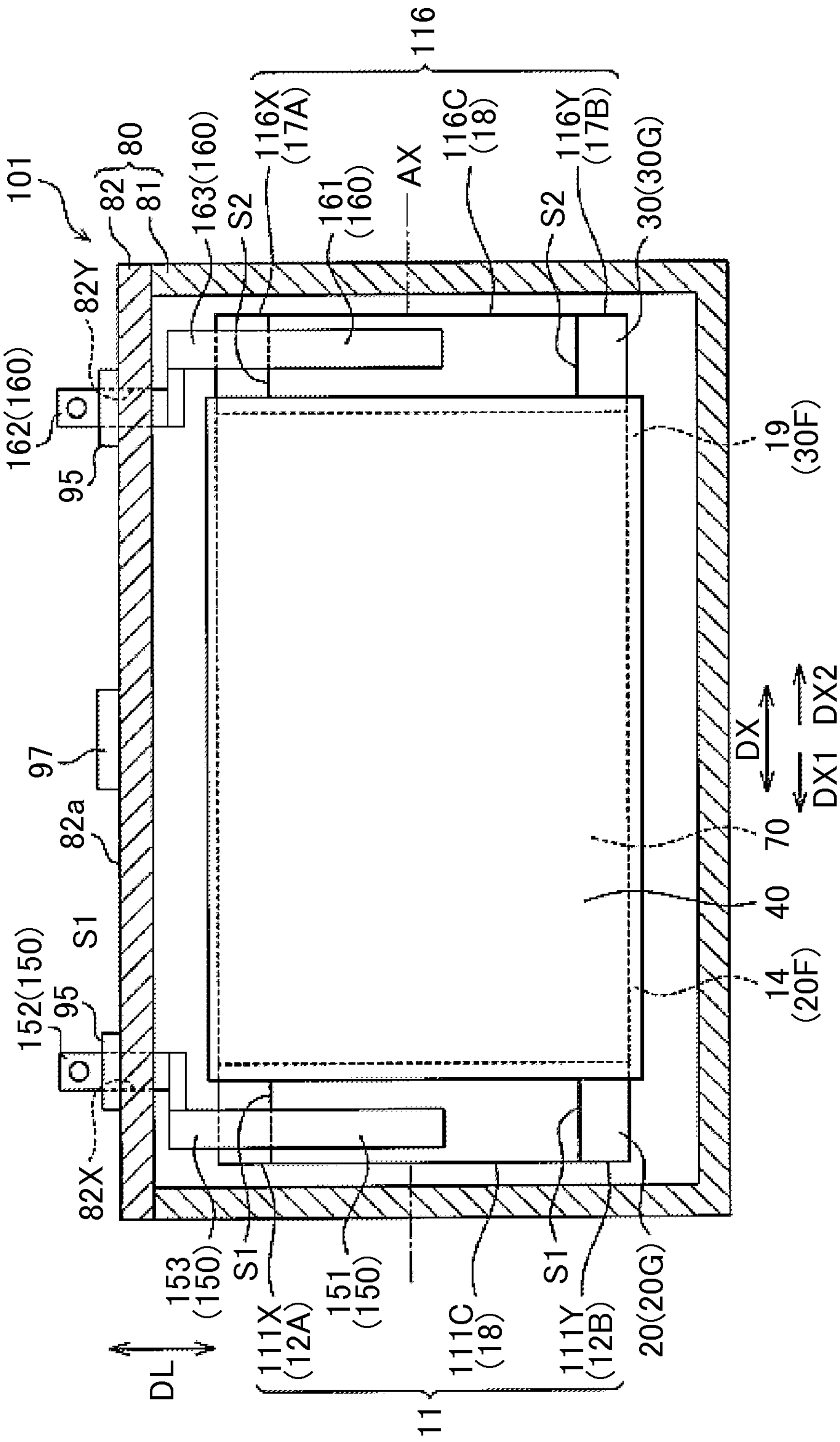
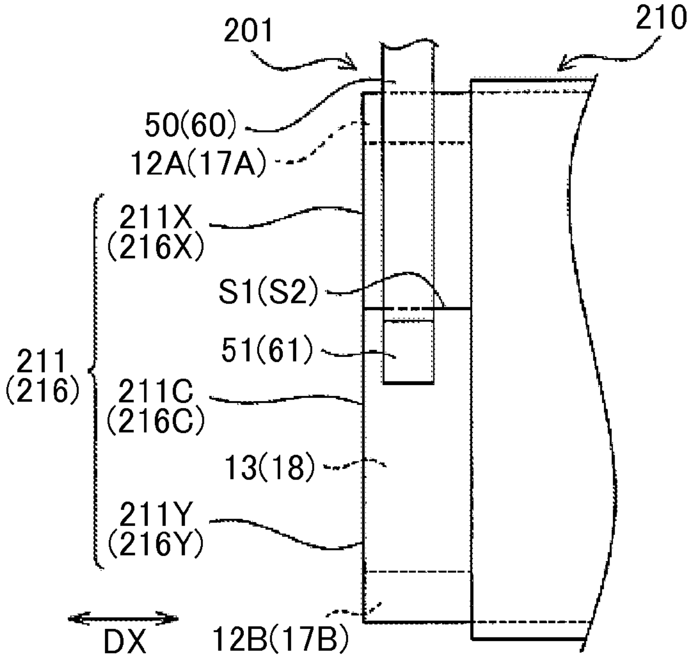


FIG. 8



116
116X
(17A)
116C
(18)
116Y
(17B)
30(30G)
AX
161
(160)
S2
163(160)
80
82
81
101
82Y
162(160)
95
19
(30F)
97
82a
DX
DX1
DX2
70
40
14
(20F)
S1
152(150)
95
82X
153
(150)
S1
111X
(12A)
151
(150)
111C
(18)
S1
111Y
(12B)
20(20G)
DL
111

FIG. 9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S1(S2)
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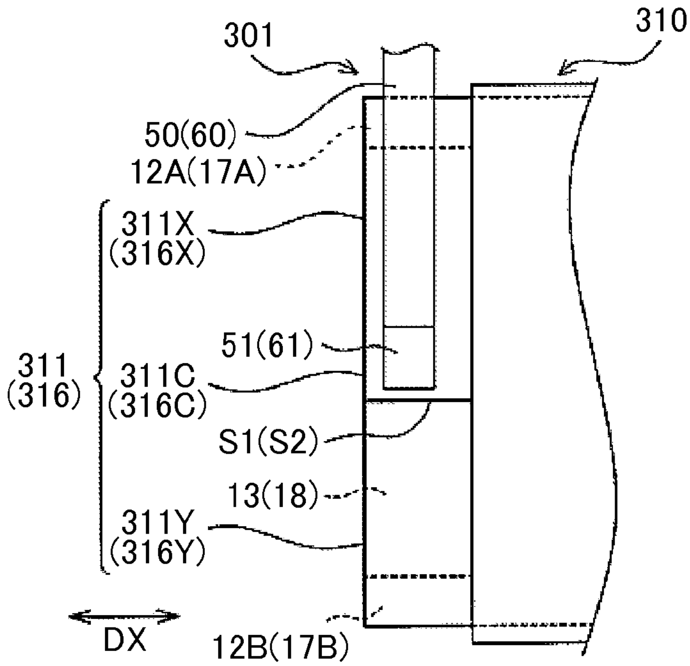
211C
(216C)
13(18)
211Y
(216Y)
DX
12B(17B)

FIG. 10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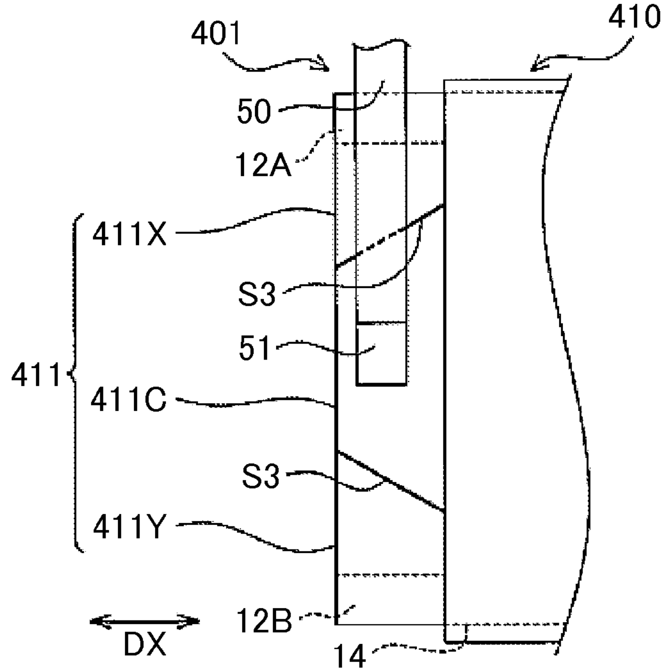
12B(17B)

FIG. 11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S3
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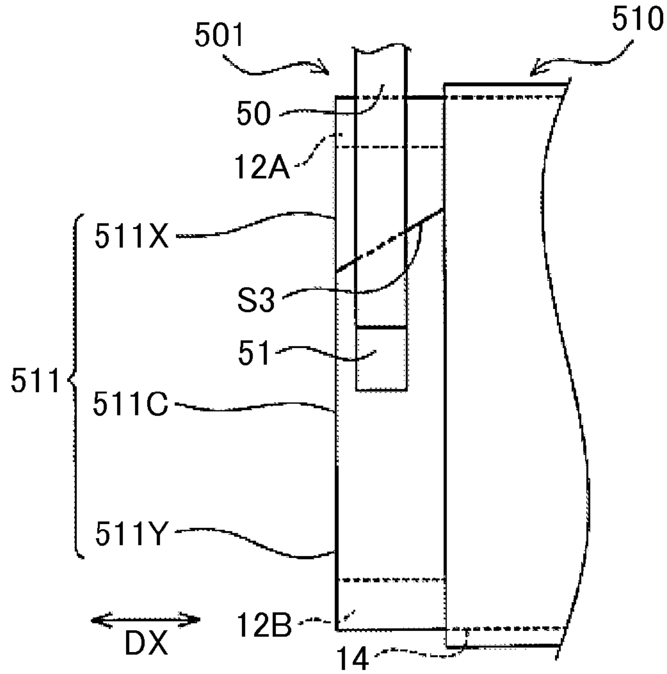
FIG. 12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511C
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FIG. 13

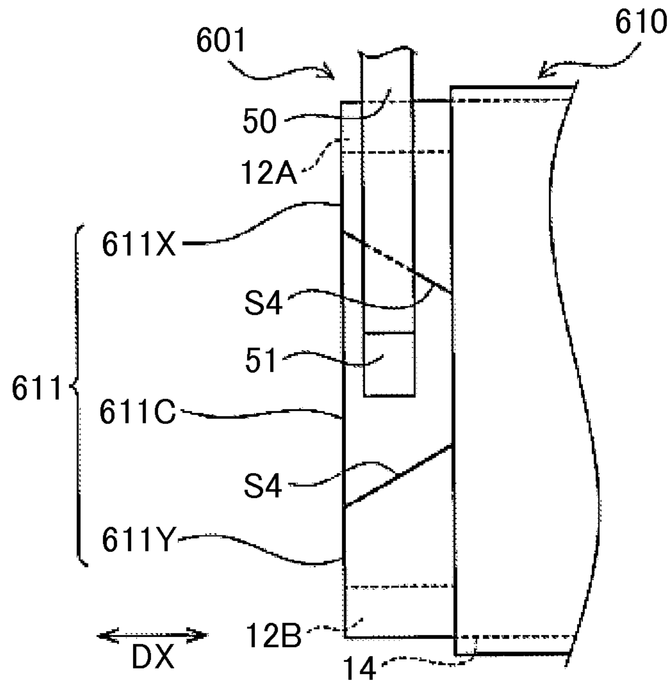
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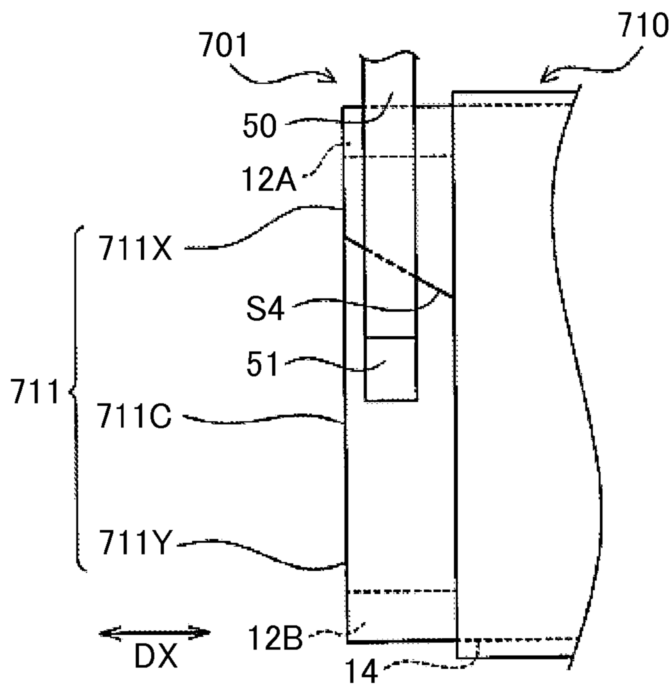
FIG. 14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S4
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711
711C
711Y
12B
DX
14

BATTERY AND METHOD OF MANUFACTURING BATTERY

TECHNICAL FIELD

The invention relates to a battery that is equipped with a flat wound electrode body that is obtained by winding an electrode plate around a winding axis and has a flat oval cross-section, and a method of manufacturing this battery.

BACKGROUND ART

In recent years, chargeable/dischargeable lithium-ion secondary batteries (hereinafter referred to simply as batteries as well) have been utilized as driving power supplies for vehicles such as hybrid vehicles, electric vehicles and the like, and portable electronic components such as notebook computers, video camcorders and the like. As such a battery, for example, there is a battery in which a collector body (corresponding to an electrode plate that will be described later) is wound around a winding axis, and a flat plate terminal (corresponding to a collector member that will be described later) is joined to a collector foil laminated region (corresponding to an exposed wound portion that will be described later) of the collector body (the electrode plate) that constitutes an electrode body (corresponding to a flat wound electrode body that will be described later) having a flat oval cross-section (e.g., a battery described in Patent Document 1).

On the other hand, in Patent Document 2, there is disclosed a battery that is designed such that a width (a dimension) W1 of a flat oval cross-section in a major axis direction is larger than a width (a dimension) W2 of plain portions of a positive electrode and a negative electrode (corresponding to electrode plates that will be described later), which constitute a group of electrodes (corresponding to a flat wound electrode body that will be described later) having the flat oval cross-section (W1>W2), in the group of the electrodes (the flat wound electrode body). Specifically, there is described a battery in which in an exposed wound portion that is obtained by winding foil exposed portions of the electrode plates, regions of the exposed wound portion that are located at both ends of the cross-section of the group of the electrodes (the flat wound electrode body) in the major axis direction respectively are lacking, and a region of the exposed wound portion that is located at a center in the major axis direction (corresponding to an exposed wound central portion that will be described later) remains (e.g., FIGS. **2***b* and **2***c* described in Patent Document 2).

RELATED ART DOCUMENTS

Patent Documents

Patent Document 1: Japanese Patent Application Publication No. 2009-26705 (JP-2009-26705 A)
Patent Document 2: Japanese Patent Application Publication No. 2006-128132 (JP-2006-128132 A)

SUMMARY OF THE INVENTION

Problem to be Solved by the Invention

However, in the battery described in Patent Document 1, the foil exposed portions constituting the exposed wound portion huddle at a joint spot of the collector member and the exposed wound portion (e.g., a thin-walled portion 33 depicted in FIG. 4 of Patent Document 1). Besides, the

exposed wound portion is formed by winding a series of the foil exposed portions around a winding axis. Therefore, there is established a mode in which the gap between radially adjacent regions of the foil exposed portions narrows as the distance to the aforementioned joint spot decreases. Thus, in the case where a gas is produced between active material layers that constitute the electrode plates in the flat wound electrode body due to, for example, a battery reaction such as initial charge or the like, the gas is unlikely to be discharged from between the active material layers to the outside of the flat wound electrode body.

In contrast, the battery described in Patent Document 2 is designed such that the ends of the active material layers directly communicate with the outside of the flat wound electrode body in the region of the flat wound electrode body that lacks part of the exposed wound portion. Thus, even though the collector member is joined to the exposed wound central portion, the gas produced between the active material layers can be reliably discharged from between the active material layers to the outside of the flat wound electrode body, through the region.

By the way, when a battery is charged/discharged, the active material layers expand/contract. Therefore, part of an electrolytic solution retained between the active material layers (a retained electrolytic solution) may be extruded from between the active material layers to the exposed wound portion (i.e., the gap formed by the foil exposed portions) and further to the outside of the flat wound electrode body. As for this electrolytic solution; the electrolytic solution extruded to the exposed wound portion (the gap between the foil exposed portions) can return again to the gap between the active material layers through a separator. However, the electrolytic solution extruded to the outside of the flat wound electrode body is likely to be accumulated on a bottom of a battery case that is spaced apart from the flat wound electrode body, and is unlikely to return to the gap between the active material layers in the flat wound electrode body.

On the other hand, in the battery described in Patent Document 2, the flat wound electrode body lacks part of the exposed wound portion as described above. Thus, part of the electrolytic solution (the retained electrolytic solution) extruded from between the active material layers directly flows out to the outside of the flat wound electrode body during charge/discharge.

The invention has been made in view of this problem. It is an object of the invention to provide a battery that allows a gas produced inside a flat wound electrode body to be easily discharged to the outside of the electrode body, and restrains an electrolytic solution (a retained electrolytic solution) extruded from the flat wound electrode body through charge/discharge from directly flowing out to the outside of the flat wound electrode body, and a method of manufacturing this battery.

Means for Solving the Problem

One aspect of the invention is a battery. The battery is equipped with a flat wound electrode body, a collector member, and a retained electrolytic solution. The flat wound electrode body is obtained by winding an electrode plate around a winding axis. The electrode plate includes a band-shaped active material layer forming portion that is obtained by forming an active material layer on a band-shaped metal foil along a first end edge as one of two end edges extending in a longitudinal direction of the metal foil, and a band-shaped foil exposed portion that has the metal foil exposed along a second end edge as the other of the two end edges of the metal foil. The flat wound electrode body has a flat oval cross-section. The flat wound electrode body has an active material layer wound portion that is obtained by winding the active material layer forming portion, and an exposed wound portion that is located on one side in an axial direction along the winding axis with respect to the active material layer wound portion and has the foil exposed portion wound. The collector member is made of a metal, and is joined to the exposed wound portion of the flat wound electrode body. The retained electrolytic solution is retained by the active material layer wound portion of the flat wound electrode body. When regions of the exposed wound portion that are located at both end portions of the oval cross-section in a major axis direction respectively and are obtained by bending back the foil exposed portion into a shape of R are defined as R-shaped exposed wound portions, regions of the exposed wound portion that include the R-shaped exposed wound portions are defined as exposed wound end portions, and a region of the exposed wound portion that is located in a central region in the major axis direction and is sandwiched between the exposed wound end portions is defined as an exposed wound central portion, the exposed wound central portion is detached from at least one of the two exposed wound end portions, while maintaining contact with the active material layer wound portion that is adjacent to the exposed wound central portion in the axial direction. The collector member is joined to the exposed wound central portion.

In the aforementioned battery, the exposed wound central portion is detached from at least one of the two exposed wound end portions, and the collector member is joined to the exposed wound central portion. Thus, even though the collector member is joined to the exposed wound central portion, the exposed wound end portion located on the side detached from the exposed wound central portion is restrained from being deformed. Consequently, at this exposed wound end portion located on the detached side, a gap can be secured between the foil exposed portions that constitute this exposed wound end portion. Accordingly, a gas produced between the active material layers can be easily discharged to the outside of the flat wound electrode body through this exposed wound end portion.

Besides, as opposed to the foregoing Patent Document 2, in addition to the exposed wound central portion, the aforementioned battery has the two exposed wound end portions. Therefore, the retained electrolytic solution extruded from between the active material layers can be temporarily retained between the foil exposed portions of the exposed wound end portions, during charge/discharge. Consequently; the battery that restrains the retained electrolytic solution extruded from the flat wound electrode body through charge/discharge from directly flowing out to the outside of the flat wound electrode body can be realized.

Incidentally, as the mode of the exposed wound portion, it is possible to mention a mode in which the exposed wound central portion is detached from both the exposed wound end portions, as well as a mode in which the exposed wound central portion is detached from one of the two exposed wound end portions. Among these modes, if the mode in which the exposed wound central portion is detached from both the exposed wound end portions is adopted, both the exposed wound end portions can be prevented from being deformed as a result of the joining of the collector member and the exposed wound central portion with each other, in comparison with a case where the mode in which the exposed wound central portion is detached from one of the exposed wound end portions is adopted. This is more preferable because a gap can be secured between the foil exposed portions at both the exposed wound end portions.

Besides, as the mode in which the exposed wound central portion and each of the exposed wound end portions are detached from each other, for example, it is possible to mention a mode in which the exposed wound central portion and each of the exposed wound end portions are detached from each other by slits that extend in the shape of waves such as sinusoidal waves or the like, as well as by slits designed to rectilinearly extend in the axial direction along the winding axis. Incidentally, even in the case where the exposed wound central portion and each of the exposed wound end portions are detached from each other by the rectilinearly extending slits, it is possible to mention a mode in which they are detached from each other by slits that extend parallel to the axial direction, or slits that gradually approach the exposed wound end portions or on the contrary, gradually move away from the exposed wound end portions respectively in accordance with the traveling from the exposed wound portion toward the active material layer wound portion in the axial direction.

Besides, as the battery that is equipped with the retained electrolytic solution, it is possible to mention, for example, a pattern in which most of the electrolytic solution present in the battery is the retained electrolytic solution while the rest exists in a small amount outside the flat wound electrode body in such a state as not to mutually flow through the retained electrolytic solution, as well as a pattern in which the entire electrolytic solution present in the battery is retained in the active material layer wound portion as the retained electrolytic solution.

Furthermore, the aforementioned battery may be designed as a battery in which the exposed wound central portion is detached from both the exposed wound end portions.

In the aforementioned battery, the exposed wound central portion is detached from both the exposed wound end portions. Therefore, both the exposed wound end portions can be prevented from being deformed as a result of the joining of the collector member and the exposed wound central portion with each other, and a gap can be secured between the foil exposed portions that constitute the exposed wound end portions respectively. Accordingly, the battery that reliably allows the gas produced between the active material layers to be discharged to the outside of the flat wound electrode body through the two exposed wound end portions can be realized.

Furthermore, any one of the aforementioned batteries may be designed as a battery in which the exposed wound central portion is constituted of a region of the exposed wound portion other than the two R-shaped exposed wound portions.

In the aforementioned battery, the region of the exposed wound portion other than the R-shaped exposed wound portions is defined as the exposed wound central portion. That is, the exposed wound central portion is secured with a longest dimension in the major axis direction. Thus, the battery in which the exposed wound central portion and the active material layer wound portion are connected to each other with a lowest resistance can be realized.

Another aspect of the invention is a method of manufacturing a battery. The battery is equipped with a flat wound electrode body, a collector member, and a retained electrolytic solution. The flat wound electrode body is obtained by winding an electrode plate around a winding axis. The electrode plate includes a band-shaped active material layer forming portion that is obtained by forming an active material layer on a band-shaped metal foil along a first end edge as one of two end edges extending in a longitudinal direction of the metal foil, and a band-shaped foil exposed portion that has the metal foil exposed along a second end edge as the other of the two end edges of the metal foil. The flat wound electrode body has a flat oval cross-section. The flat wound electrode body has an active material layer wound portion that is obtained by winding the active material layer forming portion, and an exposed wound portion that is located on one side in an axial direction along the winding axis with respect to the active material layer wound portion and has the foil exposed portion wound. The collector member is made of a metal, and is joined to the exposed wound portion of the flat wound electrode body. The retained electrolytic solution is retained by the active material layer wound portion of the flat wound electrode body. When regions of the exposed wound portion that are located at both end portions of the oval cross-section in a major axis direction respectively and are obtained by bending back the foil exposed portion into a shape of R are defined as R-shaped exposed wound portions, regions of the exposed wound portion that include the R-shaped exposed wound portions are defined as exposed wound end portion portions, and a region of the exposed wound portion that is located in a central region in the major axis direction and is sandwiched between the exposed wound end portion portions is defined as an exposed wound central portion, the exposed wound central portion is detached from at least one of the two exposed wound end portions, while maintaining contact with the active material layer wound portion that is adjacent to the exposed wound central portion in the axial direction. The collector member is joined to the exposed wound central portion. The method includes a joint process of joining the collector member to the exposed wound central portion as to the flat wound electrode body in which the exposed wound central portion of the exposed wound portion and at least one of the two exposed wound end portions of the exposed wound portion are detached from each other.

The aforementioned method of manufacturing the battery is equipped with the joint process of joining the collector member to part of the exposed wound portion, namely, the exposed wound central portion of the flat wound electrode body that has already been detached from the exposed wound end portions. Thus, by joining the collector member, a stress is unlikely to be applied to the exposed wound end portions that are detached from the exposed wound central portion even when this exposed wound central portion is deformed. Therefore, the battery can be manufactured with the gap between the foil exposed portions, which constitute the exposed wound end portions, restrained from narrowing.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of a battery according to an embodiment of the invention, a first modified embodiment of the invention, and a second modified embodiment of the invention.

FIG. **2** is a cross-sectional view (an A-A cross-section of FIG. **1**) of the battery according to the embodiment of the invention and the first modified embodiment of the invention.

FIG. **3** is a cross-sectional view (a B-B end face and a C-C end face of FIG. **2**) of the battery according to the embodiment of the invention and the first modified embodiment of the invention.

FIG. **4** is a perspective view of a positive electrode plate (a negative electrode plate) of the embodiment of the invention, the first modified embodiment of the invention, and the second modified embodiment of the invention.

FIG. **5** is an illustrative view of a method of manufacturing the battery according to the embodiment of the invention and the second modified embodiment of the invention.

FIG. **6** is an illustrative view of a joint process of the method of manufacturing the battery according to the embodiment of the invention, the first modified embodiment of the invention, and the second modified embodiment of the invention.

FIG. **7** is an illustrative view of the method of manufacturing the battery according to the first modified embodiment of the invention.

FIG. **8** is a cross-sectional view (the A-A cross-section of FIG. **1**) of the battery according to the second modified embodiment of the invention.

FIG. **9** is an illustrative view showing another embodiment of the battery.

FIG. **10** is an illustrative view showing still another embodiment of the battery.

FIG. **11** is an illustrative view showing still another embodiment of the battery.

FIG. **12** is an illustrative view showing still another embodiment of the battery.

FIG. **13** is an illustrative view showing still another embodiment of the battery.

FIG. **14** is an illustrative view showing still another embodiment of the battery.

DESCRIPTION OF REFERENCE SYMBOLS

- **1**, **101**, **201**, **301**, **401**, **501**, **601**, **701** BATTERY
- **10**, **110**, **210**, **310**, **410**, **510**, **610**, **710** ELECTRODE BODY (FLAT WOUND ELECTRODE BODY)
- **11**, **111**, **211**, **311**, **411**, **511**, **611**, **711** POSITIVE ELECTRODE EXPOSED WOUND PORTION (EXPOSED WOUND PORTION)
- **11**C, **111**C, **211**C, **311**C, **411**C, **511**C, **611**C, **711**C POSITIVE ELECTRODE EXPOSED WOUND CENTRAL PORTION (EXPOSED WOUND CENTRAL PORTION)
- **11**X, **111**X, **211**X, **311**X, **411**X, **511**X, **611**X, **711**X FIRST POSITIVE ELECTRODE EXPOSED WOUND END PORTION (EXPOSED WOUND END PORTION)
- **11**Y, **111**Y, **211**Y, **311**Y, **411**Y, **511**Y, **611**Y, **711**Y SECOND POSITIVE ELECTRODE EXPOSED WOUND END PORTION (EXPOSED WOUND END PORTION)
- **12**A FIRST POSITIVE ELECTRODE R-SHAPED EXPOSED WOUND PORTION (R-SHAPED EXPOSED WOUND PORTION)
- **12**B SECOND POSITIVE ELECTRODE R-SHAPED EXPOSED WOUND PORTION (R-SHAPED EXPOSED WOUND PORTION)
- **13** POSITIVE ELECTRODE FLAT PLATE-LIKE EXPOSED WOUND PORTION (REGION OF EXPOSED WOUND PORTION OTHER THAN TWO R-SHAPED EXPOSED WOUND PORTIONS)
- **14** POSITIVE ELECTRODE ACTIVE MATERIAL LAYER WOUND PORTION (ACTIVE MATERIAL LAYER WOUND PORTION)
- **16**, **116**, **216**, **316** NEGATIVE ELECTRODE EXPOSED WOUND PORTION (EXPOSED WOUND PORTION)
- **16**C, **116**C, **216**C, **316**C NEGATIVE ELECTRODE EXPOSED WOUND CENTRAL PORTION (EXPOSED WOUND CENTRAL PORTION)
- **16**X, **116**X, **216**X, **316**X FIRST NEGATIVE ELECTRODE EXPOSED WOUND END PORTION (EXPOSED WOUND END PORTION)
- **16**Y, **116**Y, **216**Y, **316**Y SECOND NEGATIVE ELECTRODE EXPOSED WOUND END PORTION (EXPOSED WOUND END PORTION)

17A FIRST NEGATIVE ELECTRODE R-SHAPED EXPOSED WOUND PORTION (R-SHAPED EXPOSED WOUND PORTION)
17B SECOND NEGATIVE ELECTRODE R-SHAPED EXPOSED WOUND PORTION (R-SHAPED EXPOSED WOUND PORTION)
18 NEGATIVE ELECTRODE FLAT PLATE-LIKE EXPOSED WOUND PORTION (REGION OF EXPOSED WOUND PORTION OTHER THAN TWO R-SHAPED EXPOSED WOUND PORTIONS)
19 NEGATIVE ELECTRODE ACTIVE MATERIAL LAYER WOUND PORTION (ACTIVE MATERIAL LAYER WOUND PORTION)
20 POSITIVE ELECTRODE PLATE (ELECTRODE PLATE)
20F POSITIVE ELECTRODE ACTIVE MATERIAL LAYER FORMING PORTION (ACTIVE MATERIAL LAYER FORMING PORTION)
20G POSITIVE ELECTRODE FOIL EXPOSED PORTION (FOIL EXPOSED PORTION)
21 POSITIVE ELECTRODE ACTIVE MATERIAL LAYER (ACTIVE MATERIAL LAYER)
28 POSITIVE ELECTRODE FOIL (METAL FOIL)
28S FIRST POSITIVE ELECTRODE END EDGE (FIRST END EDGE)
28T SECOND POSITIVE ELECTRODE END EDGE (SECOND END EDGE)
30 NEGATIVE ELECTRODE PLATE (ELECTRODE PLATE)
30F NEGATIVE ELECTRODE ACTIVE MATERIAL LAYER FORMING PORTION (ACTIVE MATERIAL LAYER FORMING PORTION)
30G NEGATIVE ELECTRODE FOIL EXPOSED PORTION (FOIL EXPOSED PORTION)
31 NEGATIVE ELECTRODE ACTIVE MATERIAL LAYER (ACTIVE MATERIAL LAYER)
38 NEGATIVE ELECTRODE FOIL (METAL FOIL)
38S FIRST NEGATIVE ELECTRODE END EDGE (FIRST END EDGE)
38T SECOND NEGATIVE ELECTRODE END EDGE (SECOND END EDGE)
50, **150** POSITIVE ELECTRODE COLLECTOR MEMBER (COLLECTOR MEMBER)
60, **160** NEGATIVE ELECTRODE COLLECTOR MEMBER (COLLECTOR MEMBER)
70 RETAINED ELECTROLYTIC SOLUTION
AX WINDING AXIS
DA LONGITUDINAL DIRECTION
DL MAJOR AXIS DIRECTION
DX AXIAL DIRECTION
DX**1** ONE SIDE
DX**2** THE OTHER SIDE (ONE SIDE IN (AXIAL DIRECTION))
PJ CROSS-SECTION
S**1**, S**2**, S**3**, S**4** SLIT

MODES FOR CARRYING OUT THE INVENTION

Embodiment

Next, a battery according to an embodiment of the invention will be described with reference to the drawings. First of all, a battery **1** according to the embodiment of the invention will be described with reference to FIGS. **1** to **3**. This battery **1** has a positive electrode plate **20**, a negative electrode plate **30**, and separators **40**, which are all band-shaped, and is equipped with a flat-shaped electrode body **10** that is obtained by interposing the separators **40** between this positive electrode plate **20** and this negative electrode plate **30** and winding them around a winding axis AX (see FIGS. **1** and **2**). Besides, the battery **1** is equipped with a positive electrode collector member **50** that is joined to the positive electrode plate **20** of this electrode body **10**, a negative electrode collector member **60** that is joined to the negative electrode plate **30**, and a retained electrolytic solution **70** that is retained in the electrode body **10** (a positive electrode active material layer wound portion **14** and a negative electrode active material layer wound portion **19**, which will be described later) (see FIGS. **1** and **2**). In addition to these components, the battery **1** is equipped with a battery case **80** that accommodates the electrode body **10** and the retained electrolytic solution **70** therein.

Among these components, the battery case **80** has a battery case body **81** and a sealing lid **82**, which are both made of aluminum. Among these components, the battery case body **81** assumes the shape of a bottomed rectangular box. An insulating film (not shown) that is made of resin and bent in the shape of a box is interposed between this battery case body **81** and the electrode body **10**.

Besides, the sealing lid **82** assumes the shape of a rectangular plate, closes an opening of the battery case body **81**, and is welded to this battery case body **81**. This sealing lid **82** has a first through-hole **82**X for causing the positive electrode collector member **50** to penetrate the battery case **80** from the inside thereof to the outside thereof, and a second through-hole **82**Y for causing the negative electrode collector member **60** to penetrate the battery case **80** from the inside thereof to the outside thereof (see FIG. **2**). Incidentally, insulating members **95** that are made of an insulating resin are interposed between the first through-hole **82**X and the positive electrode collector member **50** to insulate them from each other, and between the second through-hole **82**Y and the negative electrode collector member **60** to insulate them from each other, respectively. Besides, a safety valve **97** that assumes the shape of a rectangular plate is sealed to a lid surface **82***a* of the sealing lid **82** at a position between the first through-hole **82**X and the second through-hole **82**Y.

Besides, the positive electrode collector member **50** made of aluminum assumes the shape of a crank (see FIGS. **1** to **3**). This positive electrode collector member **50** is constituted of a positive electrode joint portion **51** that is located on a proximal end side (the electrode body **10** side) and is joined to the positive electrode plate **20** (a positive electrode exposed wound central portion **11**C that will be described later), a positive electrode terminal portion **52** that is located on a distal end side (outside the battery case **80**) and constitutes an external terminal of the battery **1** on the positive electrode side, and a body portion **53** that is located between this positive electrode joint portion **51** and this positive electrode terminal portion **52** (see FIG. **2**).

Among these components, as shown in FIG. **3**, the positive electrode joint portion **51** is designed to extend from the body portion **53** in a thickness direction while being flexed in the shape of a crank, and approach a center side of the electrode body **10** closer than the body portion **53**. In addition, the positive electrode joint portion **51** joins regions of a positive electrode foil exposed portion **20**G that constitute the positive electrode exposed wound central portion **11**C (which will be described later) to this positive electrode wound central portion **11**C, with the regions gathered in a minor axis direction DS of an oval shape assumed by a cross-section PJ (which will be described later) of the electrode body **10** (see FIG. **3**). Thus, the positive electrode exposed wound central portion **11**C (the respective regions of the positive electrode foil exposed portion **20**G that constitute this positive electrode exposed wound central portion) is deformed to be crushed in the minor axis direction DS (see FIG. **3**).

Besides, as is the case with the positive electrode collector member **50**, the negative electrode collector member **60** that is made of copper assumes the shape of a crank (see FIGS. **1** to **3**). This negative electrode collector member **60** is constituted of a negative electrode joint portion **61** that is located on the proximal end side (the electrode body **10**) and joined to the negative electrode plate **30** (a negative electrode exposed wound central portion **16**C that will be described later), a negative electrode terminal portion **62** that is located on the distal end side (outside the battery case **80**) and constitutes an external terminal of the battery **1** on the negative electrode side, and a body portion **63** that is located between this negative electrode joint portion **61** and this negative electrode terminal portion **62** (see FIG. **2**).

Among these components, as shown in FIG. **3**, the negative electrode joint portion **61** is designed to extend from the body portion **63** in the thickness direction while being flexed in the shape of a crank, and approach the center side of the electrode body **10** closer than the body portion **63**. In addition, the negative electrode joint portion **61** joins regions of a negative electrode foil exposed portion **30**G that constitute the negative electrode exposed wound central portion **16**C (which will be described later) to this negative electrode exposed wound central portion **16**C, with the regions gathered in the minor axis direction DS (see FIG. **3**). Thus, the negative electrode exposed wound central portion **16**C (the respective regions of the negative electrode foil exposed portion **30**G that constitute this negative electrode exposed wound central portion) is deformed to be crushed in the minor axis direction DS (see FIG. **3**).

Besides, the retained electrolytic solution **70** is obtained by adding a solute ($LiPF_6$) to a mixed organic solvent of ethylene carbonate (EC) and ethyl methyl carbonate (EMC). Incidentally, in the battery **1** according to this embodiment of the invention, the entire electrolytic solution present in the battery **1** is retained, as the retained electrolytic solution **70**, by the positive electrode active material layer wound portion **14** and the negative electrode active material layer wound portion **19**, which will be described later, and the subsequently described separators **40** that are arranged therebetween.

Besides, as shown in FIG. **1**, the electrode body **10** is a flat wound electrode body that is obtained by winding the positive electrode plate **20**, the negative electrode plate **30**, and the separators **40** around the winding axis AX in a flat shape. Incidentally, the cross-section PJ (a hatched region of FIG. **1**) that is obtained by cutting this electrode body **10** perpendicularly to the winding axis AX assumes a flat, oval shape (see FIG. **1**). In this electrode body **10**, the porous separators **40**, which are made of polyethylene, separate the positive electrode plate **20** and the negative electrode plate **30** from each other while having itself impregnated with the retained electrolytic solution **70**/retaining the retained electrolytic solution **70** therein.

Besides, as shown in the perspective view of FIG. **4**, the positive electrode plate **20** assumes the shape of a band that extends in a longitudinal direction DA, and has a positive electrode foil **28** that is made of aluminum, and two positive electrode active material layers **21** and **21** that are arranged in a band shape on both main faces **28**A and **28**A of this positive electrode foil **28** respectively. Among these components, the positive electrode foil **28** has two end edges (a first positive electrode end edge **28**S and a second positive electrode end edge **28**T) that extend in the longitudinal direction DA (see FIG. **4**). In addition, the positive electrode plate **20** has a band-shaped positive electrode active material layer forming portion **20**F that is obtained by forming the positive electrode active material layer **21** on the positive electrode foil **28** along the first positive electrode end edge **28**S of the positive electrode foil **28**, and a band-shaped positive electrode foil exposed portion **20**G that has the positive electrode foil **28** exposed along the second positive electrode end edge **28**T of the positive electrode foil **28** (see FIG. **4**).

Besides, as shown in the perspective view of FIG. **4**, the negative electrode plate **30** assumes the shape of a band that extends in the longitudinal direction DA, and has a negative electrode foil **38** that is made of copper, and two negative electrode active material layers **31** and **31** that are arranged in a band shape on both main faces **38**A and **38**A of this negative electrode foil **38** respectively. Among these components, as is the case with the positive electrode foil **28**, the negative electrode foil **38** has two end edges (a first negative electrode end edge **38**S and a second negative electrode end edge **38**T) that extend in the longitudinal direction DA (see FIG. **4**). In addition, as is the case with the positive electrode plate **20**, the negative electrode plate **30** has a band-shaped negative electrode active material layer forming portion **30**F that is obtained by forming the negative electrode active material layer **31** on the negative electrode foil **38** along the first negative electrode end edge **38**S of the negative electrode foil **38**, and a band-shaped negative electrode foil exposed portion **30**G that has the negative electrode foil **38** exposed along the second negative electrode end edge **38**T of the negative electrode foil **38** (see FIG. **4**).

The electrode body **10** that has the positive electrode plate **20**, the negative electrode plate **30** and the separators **40** as described above has the positive electrode active material layer wound portion **14** that is obtained by winding the positive electrode active material layer forming portion **20**F, and the negative electrode active material layer wound portion **19** that is obtained by winding the negative electrode active material layer forming portion **30**F. Besides, the electrode body **10** has a positive electrode exposed wound portion **11** that is located on one side DX**1** (the left side in FIG. **2**) in an axial direction DX along the winding axis AX with respect to the positive electrode active material layer wound portion **14** and is obtained by winding the positive electrode foil exposed portion **20**G, and a negative electrode exposed wound portion **16** that is located on the other side DX**2** (the right side in FIG. **2**) in the axial direction DX with respect to the negative electrode active material layer wound portion **19** and is obtained by winding the negative electrode foil exposed portion **30**G.

Among these components, the positive electrode exposed wound portion **11** is constituted of two positive electrode R-shaped exposed wound portions, namely, a first positive electrode R-shaped exposed wound portion **12**A and a second positive electrode R-shaped exposed wound portion **12**B that are located at both end portions of the aforementioned oval cross-section PJ in a major axis direction DL respectively and are formed by bending back the positive electrode foil exposed portion **20**G in the shape of R, and a positive electrode flat plate-like exposed wound portion **13** that is located between these positive electrode R-shaped exposed wound portions **12**A and **12**B and has the positive electrode foil exposed portion **20**G spread in the shape of a flat plate.

Besides, this positive electrode exposed wound portion **11** has two slits S**1** and S**1** that assume the shape of a straight line extending in the axial direction DX (see FIG. **2**). As shown in FIG. **2**, these two slits S**1** and S**1** divide the positive electrode exposed wound portion **11** into three regions in the major axis direction DL. Thus, among these three regions, the region of the positive electrode exposed wound portion **11** that is located above in FIG. **2** and includes the first positive electrode R-shaped exposed wound portion **12**A is defined as a first positive electrode exposed wound end portion **11**X. Besides, the region of the positive electrode exposed wound portion **11** that is located below in FIG. **2** and includes the second positive electrode R-shaped exposed wound portion **12**B is defined as a second positive electrode exposed wound end portion **11**Y. Furthermore, the region of the positive electrode exposed wound portion **11** that is located in a central region in the major axis direction DL and is sandwiched between the first positive electrode exposed wound end portion **11**X and the second positive electrode exposed wound end portion **11**Y is defined as a positive electrode exposed wound central portion **11**C. Incidentally, in this embodiment of the invention, the first positive electrode exposed wound end portion **11**X is constituted of the first positive electrode R-shaped exposed wound portion **12**A and part of the positive electrode flat plate-like exposed wound portion **13** that is adjacent to the first positive electrode R-shaped exposed wound portion **12**A. Besides, the second positive electrode exposed wound end portion **11**Y is constituted of the second positive electrode R-shaped exposed wound portion **12**B and part of the positive electrode flat plate-like exposed wound portion **13** that is adjacent to the second positive electrode R-shaped exposed wound portion **12**B.

Besides, this positive electrode exposed wound central portion **11**C is detached from both the first positive electrode exposed wound end portion **11**X and the second positive electrode exposed wound end portion **11**Y by the two slits S**1** and S**1**, while maintaining contact with the positive electrode active material layer wound portion **14** that is adjacent to the positive electrode exposed wound central portion **11**C in the axial direction DX. Furthermore, the positive electrode joint portion **51** of the aforementioned positive electrode collector member **50** is deposited and joined to this positive electrode exposed wound central portion **11**C. That is, through ultrasonic welding, the positive electrode joint portion **51** of the positive electrode collector member **50** is welded to this positive electrode exposed wound central portion **11**C of the first positive electrode exposed wound end portion **11**X.

Besides, the negative electrode exposed wound portion **16** is constituted of two negative electrode R-shaped exposed wound portions, namely, a first negative electrode R-shaped exposed wound portion **17**A and a second negative electrode R-shaped exposed wound portion **17**B that are located at both end portions in the aforementioned major axis direction DL respectively and are formed by bending back the negative electrode foil exposed portion **30**G in the shape of R, and a negative electrode flat plate-like exposed wound portion **18** that is located between these negative electrode R-shaped exposed wound portions **17**A and **17**B and has the negative electrode foil exposed portion **30**G spread in the shape of a flat plate.

Besides, this negative electrode exposed wound portion **16** has two slits S**2** and S**2** that assume the shape of a straight line extending in the axial direction DX (see FIG. **2**). As shown in FIG. **2**, as is the case with the positive electrode side, these two slits S**2** and S**2** divide the negative electrode exposed wound portion **16** into three regions in the major axis direction DL. Thus, among these three regions, the region of the negative electrode exposed wound portion **16** that is located above in FIG. **2** and includes the first negative electrode R-shaped exposed wound portion **17**A is defined as a first negative electrode exposed wound end portion **16**X. Besides, the region of the negative electrode exposed wound portion **16** that is located below in FIG. **2** and includes the second negative electrode R-shaped exposed wound portion **17**B is defined as a second negative electrode exposed wound end portion **16**Y. Furthermore, the region of the negative electrode exposed wound portion **16** that is located in the central region in the major axis direction DL and is sandwiched between the first negative electrode exposed wound end portion **16**X and the second negative electrode exposed wound end portion **16**Y is defined as a negative electrode exposed wound central portion **16**C. Incidentally, in this embodiment of the invention, the first negative electrode exposed wound end portion **16**X is constituted of the first negative electrode R-shaped exposed wound portion **17**A and part of the negative electrode flat plate-like exposed wound portion **18** that is adjacent to the first negative electrode R-shaped exposed wound portion **17**A. Besides, the second negative electrode exposed wound end portion **16**Y is constituted of the second negative electrode R-shaped exposed wound portion **17**B and part of the negative electrode flat plate-like exposed wound portion **18** that is adjacent to the second negative electrode R-shaped exposed wound portion **17**B.

Besides, this negative electrode exposed wound central portion **16**C is detached from both the first negative electrode exposed wound end portion **16**X and the second negative electrode exposed wound end portion **16**Y by the two slits S**2** and S**2**, while maintaining contact with the negative electrode active material layer wound portion **19** that is adjacent to the negative electrode exposed wound central portion **16**C in the axial direction DX. Furthermore, the negative electrode joint portion **61** of the foregoing negative electrode collector member **60** is deposited and joined to this negative electrode exposed wound central portion **16**C. That is, through resistance welding, the negative electrode joint portion **61** of the negative electrode collector member **60** is welded to this negative electrode exposed wound central portion **16**C of the first negative electrode exposed wound end portion **16**X.

As described above, in the battery **1** according to this embodiment of the invention, the positive electrode exposed wound central portion **11**C is detached from the two positive electrode exposed wound end portions (the first positive electrode exposed wound end portion **11**X and the second positive electrode exposed wound end portion **11**Y), and the positive electrode collector member **50** is joined to the positive electrode exposed wound central portion **11**C. Thus, even though the positive electrode collector member **50** is joined to the positive electrode exposed wound central portion **11**C, the first positive electrode exposed wound end portion **11**X and the second positive electrode exposed wound end portion **11**Y, which are detached from the positive electrode exposed wound central portion **11**C, are restrained from being deformed. Consequently, in this first positive electrode exposed wound end portion **11**X and this second positive electrode exposed wound end portion **11**Y, a gap can be secured between the positive electrode foil exposed portions **20**G that constitute these end portions. Accordingly, a gas produced between the active material layers (the positive electrode active material layer **21** and the negative electrode active material layer **31**) can be easily discharged to the outside of the electrode body **10** through this first positive electrode exposed wound end portion **11**X and this second positive electrode exposed wound end portion **11**Y.

Besides, in this battery **1**, as opposed to the aforementioned Patent Document 2, in addition to the positive electrode exposed wound central portion **11**C, the first positive electrode exposed wound end portion **11**X and the second positive electrode exposed wound end portion **11**Y remain without being removed. Thus, during charge/discharge, the retained electrolytic solution **70** extruded from between the material layers can be temporarily retained between the positive electrode foil exposed portions **20**G of the first positive electrode exposed wound end portion **11**X and the second positive electrode exposed wound end portion **11**Y. Consequently, the battery **1** that restrains the retained electrolytic solution **70** extruded from the electrode body **10** through charge/discharge from directly flowing out to the outside of the electrode body **10** can be realized.

Besides, the same holds true for the negative electrode side. That is, the negative electrode exposed wound central portion **16**C is detached from the two negative electrode exposed wound end portions (the first negative electrode exposed wound end portion **16**X and the second negative electrode exposed wound end portion **16**Y), and the negative electrode collector member **60** is joined to the negative electrode exposed wound central portion **16**C. Thus, even though the negative electrode collector member **60** is joined to the negative electrode exposed wound central portion **16**C, the first negative electrode exposed wound end portion **16**X and the second negative electrode exposed wound end portion **16**Y, which are detached from the negative electrode exposed wound central portion **16**C, axe restrained from being deformed. Consequently, in this first negative electrode exposed wound end portion **16**X and this second negative electrode exposed wound end portion **16**Y, a gap can be secured between the negative electrode foil exposed portions **300** that constitute these end portions. Accordingly, a gas produced between the active material layers (the positive electrode active material layer **21** and the negative electrode active material layer **31**) can be easily discharged to the outside of the electrode body **10** through this first negative electrode exposed wound end portion **16**X and this second negative electrode exposed wound end portion **16**Y.

Besides, as opposed to the foregoing Patent Document 2, in addition to the negative electrode exposed wound central portion **16**C, this battery **1** has the first negative electrode exposed wound end portion **16**X and the second negative electrode exposed wound end portion **16**Y. Therefore, during charge/discharge, as is the case with the positive electrode side, the retained electrolytic solution **70** extruded from between the material layers can be temporarily retained between the negative electrode foil exposed portions **30**G of the first negative electrode exposed wound end portion **16**X and the second negative electrode exposed wound end portion **16**Y Consequently, the battery **1** that restrains the retained electrolytic solution **70** extruded from the electrode body **10** through charge/discharge from directly flowing out to the outside of the electrode body **10** can be realized.

Besides, in the battery **1**, the positive electrode exposed wound central portion **11**C is detached from both the positive electrode exposed wound end portions (the first positive electrode exposed wound end portion **11**X and the second positive electrode exposed wound end portion **11**Y). Thus, both the first positive electrode exposed wound end portion **11**X and the second positive electrode exposed wound end portion **11**Y can be prevented from being deformed due to the joining of the positive electrode collector member **50** and the positive electrode exposed wound central portion **11**C with each other, and a gap can be secured between the positive electrode foil exposed portions **20**G that constitute the first positive electrode exposed wound end portion **11**X and the second positive electrode exposed wound end portion **11**Y. Accordingly, the battery **1** that reliably allows the gas produced between the active material layers to be discharged to the outside of the electrode body **10** from between the active material layers can be realized.

Besides, the same holds true for the negative electrode side. The negative electrode exposed wound central portion **16**C is detached from both the negative electrode exposed wound end portions (the first negative electrode exposed wound end portion **16**X and the second negative electrode exposed wound end portion **16**Y). Thus, both the first negative electrode exposed wound end portion **16**X and the second negative electrode exposed wound end portion **16**Y can be prevented from being deformed due to the joining of the negative electrode collector member **60** and the negative electrode exposed wound central portion **16**C with each other, and a gap can be secured between the negative electrode foil exposed portions **30**G that constitute the first negative electrode exposed wound end portion **16**X and the second negative electrode exposed wound end portion **16**Y. Accordingly, the battery **1** that reliably allows the gas produced between the active material layers to be discharged to the outside of the electrode body **10** from between the active material layers can be realized.

Next, a method of manufacturing the battery **1** according to this embodiment of the invention will be described with reference to the drawings. First of all, the positive electrode plate **20** that constitutes the electrode body **10** is fabricated according to a known method. Consequently, the positive electrode plate **20** that has the band-shaped positive electrode active material layer forming portion **20**F along the first positive electrode end edge **28**S of the positive electrode foil **28**, and the band-shaped positive electrode foil exposed portions **20**G along the second positive electrode end edge **28**T of the positive electrode foil **28** was fabricated (see FIG. **4**).

Besides, the negative electrode plate **30** is also fabricated according to the known method. Consequently, the negative electrode plate **30** that has the band-shaped negative electrode active material layer forming portion **30**F along the first negative electrode end edge **38**S of the negative electrode foil **38**, and the band-shaped negative electrode foil exposed portions **300** along the second negative electrode end edge **38**T of the negative electrode foil **38** was fabricated (see FIG. **4**).

Subsequently, the fabricated positive electrode plate **20** and the fabricated negative electrode plate **30** were cylindrically wound together with the foregoing two band-shaped separators **40** and **40**. At this time, the positive electrode plate **20** and the negative electrode plate **30** are wound such that the positive electrode foil exposed portion **20**G of the positive electrode plate **20** and the negative electrode foil exposed portion **300** of the negative electrode plate **30** are located on the other side of each other in the axial direction DX. After that, the cylindrical face was crushed from both sides to obtain a flat wound-type slit pre-formation electrode body **10**B that has a flat oval cross-section (see FIG. **5**(*a*)).

Next, a slit formation process of forming the two slits **S1** and **S1** through the positive electrode exposed wound portion **11** and forming the two slits **S2** and **S2** through the negative electrode exposed wound portion **16** will be described. In this process, a known slitter (a cutting machine) is used to form the two slits **S1** and **S1**, which detach the positive electrode exposed wound portion **11** into the positive electrode exposed wound central portion **11**C, the first positive electrode exposed wound end portion **11**X and the second positive electrode exposed wound end portion **11**Y as described above, through the positive electrode exposed wound portion **11** in the aforementioned slit pre-formation electrode body **10**B. Besides, the two slits **S2** and **S2**, which detach the negative electrode exposed wound portion **16** into the negative electrode exposed wound central portion **16**C, the first negative electrode exposed wound end portion **16**X and the second negative electrode exposed wound end portion **16**Y as described above, are formed through the negative electrode exposed wound portion **16** in the slit pre-formation electrode body **10**B. Incidentally, both the slits S**1** and S**2** are designed to rectilinearly extend along the axial direction DX.

Consequently, the electrode body **10** that is detached from all of the positive electrode exposed wound central portion **11**C, the first positive electrode exposed wound end portion **11**X and the second positive electrode exposed wound end portion **11**Y of the positive electrode exposed wound portion **11** and is detached from all of the negative electrode exposed wound central portion **16**C, the first negative electrode exposed wound end portion **16**X and the second negative electrode exposed wound end portion **16**Y of the negative electrode exposed wound portion **16** is completed (see FIG. **5**(*b*)).

Next, a joint process will be described. First of all, the positive electrode terminal portion **52** (the body portion **53**) of the positive electrode collector member **50** is passed through the first through-hole **82**X, and the negative electrode terminal portion **62** (the body portion **63**) of the negative electrode collector member **60** is passed through the second through-hole **82**Y. Thus, the sealing lid **82** that is integrally molded by the insulating members **95** in advance is prepared.

Then, the positive electrode exposed wound central portion **11**C of the aforementioned electrode body **10** (i.e., the electrode body **10** that is detached from all of the positive electrode exposed wound central portion **11**C, the first positive electrode exposed wound end portion **11**X, and the second positive electrode exposed wound end portion **11**Y of the positive electrode exposed wound portion **11**) is sandwiched between the positive electrode joint portion **51** of the positive electrode collector member **50** and a welding block (not shown) to crush the positive electrode exposed wound central portion **11**C (the respective regions of the positive electrode foil exposed portions **20**G that constitute this positive electrode exposed wound central portion) in the minor axis direction DS.

Subsequently, the positive electrode collector member **50** and the positive electrode exposed wound central portion **11**C are ultrasonically welded to each other. Specifically, the positive electrode joint portion **51** of the positive electrode collector member **50** and the positive electrode exposed wound central portion **11**C are ultrasonically welded to each other through the use of a known ultrasonic welder. Thus, the positive electrode collector member **50** and the electrode body **10** are joined to each other.

Besides, the same process as on the positive electrode side is carried out on the negative electrode side. However, the difference consists in that the negative electrode collector member **60** and the negative electrode exposed wound central portion **16**C are resistance-welded to each other through the use of a known resistance welder. Consequently, as is the case with the positive electrode side, the negative electrode collector member **60** and the electrode body **10** are joined to each other.

After that, the electrode body **10** is accommodated in the battery case body **81**. The battery case body **81** is sealed through welding by the sealing lid **82** that is penetrated by the positive electrode collector member **50** and the negative electrode collector member **60**, which are joined to this electrode body **10**. Furthermore, the electrolytic solution is injected from a liquid injection hole (not shown), the liquid injection hole is sealed while reducing the pressure in the battery case **80** to −80 kPa, and then initial charge is carried out to complete the battery **1** (see FIGS. **1** to **3**).

Incidentally, in the aforementioned initial charge, the battery **1** was charged with a current value of 1 C until the voltage (the inter-terminal voltage) of the battery **1** became equal to 4.1 V under a temperature environment of 25° C., and then was charged until the current value became equal to 0.02 C while this voltage was held (constant current-constant voltage charge). The charge time in this case was 85 minutes.

Besides, the inventors carried out similar initial charge in manufacturing a battery (hereinafter referred to also as a comparative battery) that does not have slits through a positive electrode wound portion of an electrode body or a negative electrode exposed wound portion of the electrode body as opposed to the battery **1** according to this embodiment of the invention. It is apparent that the charge time in this case is 88 minutes, and that the charge time of the battery **1** according to this embodiment of the invention is shorter.

This is considered to result from the fact that if a gas produced between the active material layers through initial charge remains stagnant between the active material layers, part of the electrolytic solution cannot exist between the positive electrode active material layer and the negative electrode active material layer, and hence the progress of a charge reaction is delayed in comparison with a battery between which and an active material layer no gas stagnates. Besides, the comparative battery does not have slits through an exposed wound portion, and hence the gap between regions of a foil exposed portion that are adjacent to each other in a radial direction is narrow at a joint spot of a collector member and the exposed wound portion, and the gap narrows as the distance to this joint spot decreases. On the other hand, in the battery **1** subjected to the foregoing joint process, as shown in FIG. **6**(*b*), the gap between the foil exposed portions at the exposed wound central portion is narrow, but the gap between the foil exposed portions at the exposed wound end portions is secured. That is, it is considered that the battery **1** according to this embodiment of the invention is designed to be more likely to discharge the gas produced between the active material layers through initial charge to the outside of the electrode body through the exposed wound portion (the exposed wound end portions), than the comparative battery.

The method of manufacturing the battery **1** according to this embodiment of the invention is equipped with a joint process of joining the positive electrode collector member **50** to the positive electrode exposed wound central portion **11**C of the electrode body **10** that has already been detached from the first positive electrode exposed wound end portion **11**X and the second positive electrode exposed wound end portion **11**Y as parts of the positive electrode exposed wound portion **11**. Thus, by joining the positive electrode collector member **50** to the positive electrode exposed wound central portion **11**C, a stress is unlikely to be applied to the first positive electrode exposed wound end portion **11**X and the second positive electrode exposed wound end portion **11**Y that are detached from this positive electrode exposed wound central portion **11**C even when this positive electrode exposed wound central portion **11**C is deformed. Accordingly, the battery **1** can be manufactured with the gap between the positive electrode foil exposed portions **200**, which constitute the first positive electrode exposed wound end portion **11**X and the second positive electrode exposed wound end portion **11**Y, restrained from narrowing.

Besides, as for the negative electrode side as well, as is the case with the positive electrode side, a joint process of joining the negative electrode collector member **60** to the negative electrode exposed wound central portion **16**C of the electrode body **10** that has already been detached from the first negative electrode exposed wound end portion **16**X and the second negative electrode exposed wound end portion **16**Y as parts of the negative electrode exposed wound portion **16** is provided.

Thus, by joining the negative electrode collector member **60** to the negative electrode exposed wound central portion **16**C, a stress is unlikely to be applied to the first negative electrode exposed wound end portion **16**X and the second negative electrode exposed wound end portion **16**Y that are detached from this negative electrode exposed wound central portion **16**C even when this negative electrode exposed wound central portion **16**C is deformed. Accordingly, the battery **1** can be manufactured with the gap between the negative electrode foil exposed portions **30**G, which constitute the first negative electrode exposed wound end portion **16**X and the second negative electrode exposed wound end portion **16**Y, restrained from narrowing.

First Modified Embodiment

Next, the first modified embodiment of the invention will be described with reference to the drawings. This first modified embodiment of the invention is different from the aforementioned embodiment of the invention in that a flat wound electrode body is completed after slits are formed through an exposed wound portion of a cylindrical electrode body. Thus, the difference from the embodiment of the invention will be mainly described, and the description of similar parts will be omitted or simplified. Incidentally, a similar operation and a similar effect are created as to the similar parts. Besides, the description will be given with like reference numerals allocated to like contents respectively.

A method of manufacturing the battery **1** according to this first modified embodiment of the invention will be described with reference to the drawings. First of all, the positive electrode plate **20** and the negative electrode plate **30**, which have been fabricated according to a known method, were cylindrically wound around the winding axis AX together with the two band-shaped separators **40** and **40**. At this time, as is the case with the embodiment of the invention, the positive electrode plate **20** and the negative electrode plate **30** are wound such that the positive electrode foil exposed portions **20**G of the positive electrode plate **20** and the negative electrode foil exposed portions **30**G of the negative electrode plate **30** are located on the other side of each other respectively in the axial direction DX. Consequently, a cylindrical wound-type slit pre-formation electrode body **107** is completed (see FIG. **7**(*a*)).

Next, a process of forming the slits S**1** (S**2**) through the positive electrode exposed wound portion **11** (the negative electrode exposed wound portion **16**) will be described. Incidentally, this first modified embodiment of the invention is different from the embodiment of the invention in which the slits S**1** and S**2** are formed through the flat wound-type slit pre-formation electrode body **10**B, in that the slits S**1** and S**2** are formed through the cylindrical wound-type slit pre-formation electrode body **10**J.

That is, in this process, the two slits S**1** and S**1** that rectilinearly extend along the axial direction DX were formed through the positive electrode exposed wound portion **11** of the cylindrical wound-type slit pre-formation electrode body **10**J, through the use of a known slitter (a cutting machine) (see FIG. **7**(*b*)). Specifically, the two slits S**1** and S**1** that rectilinearly extend along the axial direction DX were formed through the positive electrode exposed wound portion **11** in such a manner as to sandwich the winding axis AX between the two slits S**1** and S**1** to be formed, through the use of the slitter.

Besides, as for the negative electrode side as well, by the same token, the two slits S**2** and S**2** that rectilinearly extend along the axial direction DX were formed through the negative electrode exposed wound portion **16** of the cylindrical wound-type slit pre-formation electrode body **10**J (see FIG. **7**(*b*)). Consequently, a cylindrical wound-type electrode body **10**K that has the two slits S**1** and S**1** and the two slits S**2** and S**2** is completed.

Next, a cylindrical face of the cylindrical wound-type electrode body **10**K is crushed to be deformed into a flat wound type. Thus, the electrode body **10** similar to that of the foregoing embodiment of the invention is completed (see FIG. **5**(*b*)).

Incidentally, after the deformation process, the battery **1** is manufactured similarly to the foregoing embodiment of the invention. Therefore, the description will be omitted.

Second Modified Embodiment

Next, the second modified embodiment of the invention will be described with reference to the drawings. As is the case with the embodiment of the invention, a battery **101** according to this second modified embodiment of the invention has two slits that split an exposed wound portion into two exposed wound end portions and an exposed wound central portion. However, the battery **101** is different from the battery **1** according to the aforementioned embodiment of the invention in that the exposed wound central portion is made longer in the major axis direction DL than in the embodiment of the invention and is constituted of a region of the exposed wound portion other than the two R-shaped exposed wound portions.

That is, as shown in FIG. **8**, a positive electrode exposed wound portion **111** in the electrode body **110** according to this second modified embodiment of the invention is constituted of the first positive electrode R-shaped exposed wound portion **12**A, the second positive electrode R-shaped exposed wound portion **12**B and the positive electrode flat plate-like exposed wound portion **13** as is the case with the foregoing embodiment of the invention.

However, in this second modified embodiment of the invention, a first positive electrode exposed wound end portion **111**X is constituted of the first positive electrode R-shaped exposed wound portion **12**A, a second positive electrode exposed wound end portion **111**Y is constituted of the second positive electrode R-shaped exposed wound portion **12**B, and a positive electrode exposed wound central portion **111**C is constituted of the positive electrode flat plate-like exposed wound portion **13** as a region of the positive electrode exposed wound portion **111** other than the two positive electrode R-shaped exposed wound portions **12**A and **12**B.

Besides, as shown in FIG. **8**, a negative electrode exposed wound portion **116** is constituted of the first negative electrode R-shaped exposed wound portion **17**A, the second negative electrode R-shaped exposed wound portion **17**B and the negative electrode flat plate-like exposed wound portion **18** as is the case with the foregoing embodiment of the invention.

However, in this second modified embodiment of the invention, a first negative electrode exposed wound end portion **116**X is constituted of the first negative electrode R-shaped exposed wound portion **17**A, a second negative electrode exposed wound end portion **116**Y is constituted of the second negative electrode R-shaped exposed wound portion **17**B, and a negative electrode exposed wound central portion **116**C is constituted of the negative electrode flat plate-like exposed wound portion **18** as a region of the negative electrode exposed wound portion **116** other than the two negative electrode R-shaped exposed wound portions **17**A and **17**B.

In addition to the exertion of a similar operation and a similar effect due to a configuration similar to that of the embodiment of the invention, in the battery **101** according to this second modified embodiment of the invention, the positive electrode flat plate-like exposed wound portion **13** as the region of the positive electrode exposed wound portion **111** other than the positive electrode R-shaped exposed wound portions **12**A and **12**B is defined as the positive electrode exposed wound central portion **111**C. That is, the positive electrode exposed wound central portion **111**C is secured with a longest dimension in the major axis direction DL. Thus, the battery **101** in which the positive electrode exposed wound central portion **111**C and the positive electrode active material layer wound portion **14** are connected to each other with a lowest resistance can be realized.

Besides, the same holds true for the negative electrode side as well. That is, the negative electrode flat plate-like exposed wound portion **18** as the region of the negative electrode exposed wound portion **116** other than the negative electrode R-shaped exposed wound portions **17**A and **17**B is defined as the negative electrode exposed wound central portion **116**C. That is, the negative electrode exposed wound central portion **116**C is secured with a longest dimension in the major axis direction DL. Thus, the battery **101** in which the negative electrode exposed wound central portion **116**C and the negative electrode active material layer wound portion **19** are connected to each other with a lowest resistance can be realized.

The invention has been described hereinabove referring to the embodiment thereof, the first modified embodiment thereof, and the second modified embodiment thereof. However, the invention is not limited to the aforementioned embodiment thereof or the like. It goes without saying that the invention is applicable after being appropriately altered without departing from the gist thereof.

For example, the embodiment of the invention and the like present the mode in which the positive electrode exposed wound central portion **11**C (**111**C) is detached from both the positive electrode exposed wound end portions **11**X and **11**Y (**111**X and **111**Y) by the two slits S**1** and S**1** (e.g., see FIGS. **2** and **8**). However, it is also acceptable to realize a battery **201** (**301**) that is equipped with an electrode body **210** (**310**) in which a positive electrode exposed wound central portion **211**C (**311**C) is detached from one of two positive electrode exposed wound end portions **211**X and **211**Y (**311**X and **311**Y) by the single slit S**1** (see FIGS. **9** and **10**). Besides, as for the negative electrode side, it is also acceptable to realize the battery **201** (**301**) that is equipped with the electrode body **210** (**310**) in which a negative electrode exposed wound central portion **216**C (**316**C) is detached from one of two negative electrode exposed wound end portions **216**X and **216**Y (**316**X and **316**Y) by the single slit S**2** (see FIGS. **9** and **10**).

Besides, the embodiment of the invention and the like present the example in which the rectilinearly extending slits S**1** and S**2** are formed as the mode in which the exposed wound central portion **11**C (**16**C, **111**C, **116**C) and each of the exposed wound end portions **11**X (**11**Y, **16**X, **16**Y, **111**X, **111**Y, **116**X, **116**Y) is detached from each other (e.g., see FIGS. **2** and **8**). However, the exposed wound central portion and each of the exposed wound end portions can also be detached from each other by other types of slits, for example, slits that extend in the shape of waves such as rectangular waves, sinusoidal waves or the like.

Besides, the embodiment of the invention and the like exemplify the slits S**1** and S**2** that extend parallel to each other along the axial direction DX. However, for example, as shown in FIGS. **11** and **12**, it is also acceptable to realize a battery **401** (**501**) that is equipped with an electrode body **410** (**510**) that is detached by slits S**3** designed to gradually approach positive electrode exposed wound end portions **411**X and **411**Y (**511**X and **511**Y) from a positive electrode exposed wound central portion **411**C (**511**C) in accordance with the traveling from a positive electrode exposed wound portion **411** (**511**) side toward the positive electrode active material layer wound portion **14** side (rightward in the drawings) in the axial direction DX. Besides, the same holds true for the negative electrode side.

On the contrary, for example, as shown in FIGS. **13** and **14**, it is also acceptable to realize a battery **601** (**701**) that is equipped with an electrode body **610** (**710**) that is detached by slits S**5** designed to gradually move away from positive electrode exposed wound end portions **611**X and **611**Y (**711**X and **711**Y) and gradually approach a positive electrode exposed wound central portion **611**C (**711**C), in accordance with the traveling from a positive electrode exposed wound portion **611** (**711**) side toward the positive electrode active material layer wound portion **14** side (rightward in the drawings) in the axial direction DX. Besides, the same holds true for the negative electrode side.

The invention claimed is:

1. A battery comprising:

a flat wound electrode body that is obtained by winding an electrode plate around a winding axis, the electrode plate including a band-shaped active material layer forming portion that is obtained by forming an active material layer on a band-shaped metal foil along a first end edge as one of two end edges extending in a longitudinal direction of the metal foil, and a band-shaped foil exposed portion that has the metal foil exposed along a second end edge as the other of the two end edges of the metal foil, that has a flat oval cross-section, and that has an active material layer wound portion that is obtained by winding the active material layer forming portion, and an exposed wound portion that is located on one side in an axial direction along the winding axis with respect to the active material layer wound portion and has the foil exposed portion that is wound;

a collector member that is made of a metal, and is joined to the exposed wound portion of the flat wound electrode body; and

a retained electrolytic solution that is retained by the active material layer wound portion of the flat wound electrode body, wherein

when regions of the exposed wound portion that are located at both end portions of the oval cross-section in a major axis direction respectively and are obtained by bending back the foil exposed portion into a shape of R are defined as R-shaped exposed wound portions, regions of the exposed wound portion that include the R-shaped exposed wound portions are defined as exposed wound end portions, and a region of the exposed wound portion that is located in a central region in the major axis direction and is sandwiched between the exposed wound end portions is defined as an exposed wound central portion,

the exposed wound central portion is detached from at least one of the two exposed wound end portions, while maintaining contact with the active material layer wound portion that is adjacent to the exposed wound central portion in the axial direction, and

the collector member is joined to the exposed wound central portion.

2. The battery according to claim **1**, wherein

the exposed wound central portion is detached from both the exposed wound end portions.

3. The battery according to claim 1, wherein the exposed wound central portion is constituted by a region of the exposed wound portion other than the two R-shaped exposed wound portions.

4. A method of manufacturing a battery that is equipped with:

a flat wound electrode body that is obtained by winding an electrode plate around a winding axis, the electrode plate including a band-shaped active material layer forming portion that is obtained by forming an active material layer on a band-shaped metal foil along a first end edge as one of two end edges extending in a longitudinal direction of the metal foil, and a band-shaped foil exposed portion that has the metal foil exposed along a second end edge as the other of the two end edges of the metal foil, that has a flat oval cross-section, and that has an active material layer wound portion that is obtained by winding the active material layer forming portion, and an exposed wound portion that is located on one side in an axial direction along the winding axis with respect to the active material layer wound portion and has the foil exposed portion that is wound;

a collector member that is made of a metal, and is joined to the exposed wound portion of the flat wound electrode body; and

a retained electrolytic solution that is retained by the active material layer wound portion of the flat wound electrode body, wherein

when regions of the exposed wound portion that are located at both end portions of the oval cross-section in a major axis direction respectively and are obtained by bending back the foil exposed portion into a shape of R are defined as R-shaped exposed wound portions, regions of the exposed wound portion that include the R-shaped exposed wound portions are defined as exposed wound end portions, and a region of the exposed wound portion that is located in a central region in the major axis direction and is sandwiched between the exposed wound end portions is defined as an exposed wound central portion,

the exposed wound central portion is detached from at least one of the two exposed wound end portions, while maintaining contact with the active material layer wound portion that is adjacent to the exposed wound central portion in the axial direction, and

the collector member is joined to the exposed wound central portion,

the method comprising:

joining the collector member to the exposed wound central portion as to the flat wound electrode body in which the exposed wound central portion of the exposed wound portion and at least one of the two exposed wound end portions of the exposed wound portion are detached from each other.

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